

Atmospheric Mercury in Vermont and New England: Measurement of deposition, surface exchanges and assimilation in terrestrial ecosystems

Final Project Report – Introduction – 1/16/2009

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Project Overview

The primary objectives of this project were to 1) continue year-round monitoring of mercury wet-deposition in the Lake Champlain Basin; 2) establish measurements of speciated (GEM, RGM, HGP) ambient atmospheric mercury; 3) conduct measurements of surface-atmosphere exchanges of gaseous elemental mercury (GEM) over a New England forest; and 4) evaluate possible pathways for assimilation of atmospheric mercury into the biota of terrestrial ecosystems of the region.

The project was designed as part of an integrated program of research and monitoring of atmospheric deposition in the Lake Champlain Basin coordinated with NOAA, the Lake Champlain Research Consortium, The Vermont Agency of Natural Resources, and the Vermont Monitoring Cooperative. The project investigators participated in several major regional mercury research initiatives providing a connection between mercury research at Underhill, VT and regional efforts. The characterization and analysis of mercury deposition, surface exchanges, and assimilation in terrestrial ecosystems provided by this study has provided critical understanding of potential mercury response to regional and national reductions in atmospheric mercury emissions. The observational results and analysis provided by this study have applicability to regional assessments of mercury deposition, ecosystem mercury retention and the extent to which atmospherically deposited mercury is transferred to high trophic-level organisms in terrestrial environments.

Project Description

1. Background

Atmospheric mercury research began at Proctor Maple Research Center in Underhill, Vermont in 1992. Sponsored by EPA and NOAA, in collaboration with the University of Vermont and University of Michigan, the station embarked on an event-based sampling program for mercury in precipitation, aerosol particles and mercury vapor. Collecting rain and snowfall storm by storm, rather than the more common weekly sampling, allowed the investigators to relate the mercury concentration patterns in individual storms to specific air mass trajectories. In this way, geographic sources of atmospheric mercury emissions were more easily isolated. Underhill has the longest continuous running event-based mercury wet-deposition station *in the world*. This project provided a crucial comparison and critical evaluation of the 3 major types of mercury wet-deposition collectors used in regional and national wet-deposition networks. This comparison and analysis provided the information needed to transition the long-term mercury observations at Underhill using the University of Michigan MICB collector to the national Mercury Deposition Network monitoring protocol and collector. Inclusion of the Underhill site in the national network was an important step needed to provide national representation and evaluation of mercury risks to Vermont and Northern New England.

Vermont has also been a locus for pioneering research on the fate and transport of mercury in terrestrial and aquatic environments. Because of its quality high temporal-resolution data and its location in the Lake Champlain basin, estimates of atmospheric mercury deposition derived from the measurements at Underhill have been and continue to be used by scientists investigating mercury in terrestrial and aquatic environments. These programs have fostered a community of researchers including atmospheric scientists, hydrologists, limnologists, ecologists and biogeochemists who actively collaborate on the study of the impact of mercury on Vermont's and New England's ecosystems.

This consortium of researchers identified critical areas requiring research in order to advance understanding of the mercury exchanges between ecosystems and the atmosphere, the redistribution of mercury in the landscape, and the transfer of atmospherically deposited mercury to biota. The group formulated research questions that would provide substantial new insights in a short period of time and that would provide information useful for the assessment of mercury risks and impacts throughout the Northeastern USA. Eight priority tasks identified by the group were the focus of this project.

- 1) Extend the long-term record of mercury concentration in precipitation and gas-phase mercury (TGM) in air at Underhill, VT.
- 2) Characterize reactive gas phase mercury (RGM) concentrations at Underhill and other locations.
- 3) Characterize diurnal and daily variations in TGM and RGM within different seasons at Underhill.
- 4) Obtain measurements of vapor-phase mercury exchanges between the atmosphere and the landscape over several different landscape elements. And use these flux measurements to:
 - a. properly parameterize and validate micrometeorological models for atmosphere-surface mercury exchanges.
 - b. assess the magnitude of mercury remission from soils and plant canopies.
- 5) Use the refined and validated micrometeorological models together with the ambient TGM and RGM observations at Underhill to make improved estimates of net mercury deposition.
- 6) Measure rates of mercury accumulation in plant foliage and canopy throughfall over several growing seasons for comparison with model-based estimates of net TGM and RGM deposition.
- 7) Improve confidence in estimates of mercury retention within different landscape elements by comparing measured soil mercury inventories with inventories predicted by net deposition hindcasts using models for atmosphere-surface mercury exchanges and observations of mercury exports.
- 8) Make initial assessments of the potential transfer of atmospherically deposited mercury from plant foliage to high trophic level biota in terrestrial ecosystems.

The project attempted to address each of these objectives. Unfortunately, due to a Congressional rescission of the EPA budget and subsequent program budget decisions at EPA, the project did not receive funding for years 4 and 5 of the planned project. Thus we were not able to address all of the objectives to the extent described in the project proposal. Tasks 1-3 were deemed foundation tasks essential for developing reliable estimates of total atmospheric mercury deposition for Vermont and other northeastern states. Tasks 1-3 were completed as anticipated with support from funding partners and EPA-ORD. Research directed to Task 4 was more limited in scope than envisioned in the project proposal due to both the budget shortfall and due to an accident which disabled the forest-canopy observation tower during early stages of the project. The budget shortfall limited our ability to construct and deploy the planned mobile mercury measurement facility and to conduct flux measurements over different surface types. However, with supplementary funding from NOAA and VTANR we were able to conduct some short-term observations primarily for ambient-air speciation measurements near lake-level in the Lake Champlain Basin. Task 5 (incomplete due to funding rescission) we expect to address in the near future under separate funding despite the limited observations achieved under Task 4. Tasks 6 and 7 were eliminated due to the budget shortfall. Task 8 was satisfactorily addressed despite reduced activity due to the budget shortfall.

During the study, Task 2 was modified to include characterization of particulate-bound mercury (PBM, also referred to as HGP). This measurement was added after acquisition of a Tekran 1135 continuous particulate mercury measurement module, allowing more complete characterization of ambient atmospheric mercury. Task 3 was subsequently modified to include analysis and characterization of GEM, RGM, and HGP. An additional Task 9 was added during the project as the potential importance of atmospheric sources of methyl-mercury was recognized through the food-web study segment of the project (Task 8). We added measurements of methyl-mercury in monthly composite samples of precipitation in order to characterize the potential wet flux of methyl-mercury to both terrestrial and aquatic ecosystems. Late in the project, supplemental funds from NOAA allowed the analysis of event precipitation samples for methyl-mercury during the warm season. This provided the possibility to evaluate meteorological and transport conditions that might give rise to elevated methyl-mercury concentrations and wet-deposition.

As modified during the project, the principal objectives and tasks break down into the following subprojects:

- Long-term record of event-based precipitation mercury concentration and deposition at Underhill, VT
- Initial Characterization of precipitation methyl-mercury concentration and deposition
- Characterization of ambient atmospheric mercury speciation and concentrations (GEM, RGM, and HGP) at Underhill and other locations
- Identification of source regions and meteorological conditions giving rise to elevated wet and dry mercury deposition
- Initial measurements of GEM exchanges over a forest canopy
- Mercury assimilation in a terrestrial food web
- Coordination with national, regional, and state mercury research

Results from these projects have been transferred to natural resource management and human health communities via participation by project-affiliated scientists in the Governor's Task Force on Mercury, regional, national, and international meetings, and scientific publications.

Project Results

Results will be reviewed by subproject in separate documents. The methodologies employed will be briefly reviewed for each task.

Section 0 – **Executive Summary** – “FR-sec0-ExecSum-2009-01-16.pdf”

Section 1 – **Introduction** – “FR-sec1-Introduction-2009-01-16.pdf”

Section 2a – **Event-Based Wet Deposition** – “FR-sec2a-Event-Wet-2009-01-16.pdf”

Section 2b – **Collector Comparison Manuscript** – “FR-sec2b-Collector-Comparison-2009-01-16.pdf”

Section 2c – **Long-Term Wet Deposition Manuscript** – “FR-sec2c-Long-Term-Record-2009-01-16.pdf”

Section 3a – **Ambient Air Mercury Speciation Studies** – “FR-sec3a-AmbHgSpec-2009-01-16.pdf”

Section 3b – **Shorham, VT Short-term Study** – “FR-sec3b-Shoreham-2009-01-16.pdf”

Section 4 – **GEM Flux Measurements** – “FR-sec4-GEMFlux-2009-01-16.pdf”

Section 5 – **Terrestrial Food-Web Manuscript** – “FR-sec5-Food-Web-2009-01-16.pdf”

Section 6 – **Additional Project Activities** – “FR-sec6-EndSections-2009-01-16.pdf”